PAPERS on Economics & Evolution

MAX-PLANCK-GESELLSCHAFT

1013

Will imitators follow pioneer consumers in the adoption of solar thermal systems? Empirical evidence for North-West Germany

by

Julia Sophie Wörsdorfer
Wolfhard Kaus

The *Papers on Economics and Evolution* are edited by the Evolutionary Economics Group, MPI Jena. For editorial correspondence, please contact: evopapers@econ.mpg.de

ISSN 1430-4716

Max Planck Institute of Economics
Evolutionary Economics Group
Kahlaische Str. 10
07745 Jena, Germany
Fax: ++49-3641-686868

Will imitators follow pioneer consumers in the adoption of solar thermal systems? Empirical evidence for North-West Germany*

Julia Sophie Woersdorfer†, Wolfhard Kaus‡

Abstract

In Germany, solar thermal systems (STS) have only diffused to a minor extent yet. This paper analyzes, which demand side factors are decisive for the further proliferation of this environmentally benign technology. Making use of a consumer survey in North-West Germany in 2007, we examine the following parameters: positive environmental attitude, knowledge of the applicability of STS to satisfy consumer needs, and the presence of STS among peer consumers. Drawing upon theoretical foundations from innovation economics and evolutionary consumer theory, we posit that these variables play a different role at distinct stages of the product's diffusion process. Among nonowners, concrete plans to purchase a system within the subsequent two years are distinguished from the general interest to invest into this technology within the next five years. Probit-models are estimated to test our hypotheses. Our results do not indicate a strong take-off of product diffusion within the next years. By generating interest for the product, knowledge and environmental attitude as well as household income are important determinants of prospective adoptions on the part of the potential imitators. However, only the behavior of peers appears to act as a trigger to the diffusion of this technology.

Keywords: innovation diffusion, solar thermal systems, consumer motivations, consumer knowledge

JEL classification: D12, O33, Q42, Q55

*We would like to express our gratitude towards Jens Clausen (Borderstep Institute, Hanover, Germany) for providing the survey data. We benefitted greatly from discussions with members of the $WENKE^2$ project as well as Uwe Cantner and Oliver Kirchkamp. We further thank Ulrich Witt for comments on an earlier version of the manuscript. Many thanks also go the participants at the $WENKE^2$ conference *"Wege zum nachhaltigen Konsum, Häuslicher Energiekonsum und Ernährung, Abschlusstagung"* in Oldenburg, April 2010. Financial support of the Max Planck Institute of Economics as well as the Federal Ministry of Education and Research (BMBF) is kindly acknowledged (grant 01UN0602C). The usual disclaimer applies.

†*Corresponding author.* Max Planck Institute of Economics, Evolutionary Economics Group, Kahlaische Straße 10, 07745 Jena, Germany, woersdorfer@econ.mpg.de.

‡Max Planck Institute of Economics, Evolutionary Economics Group, Kahlaische Straße 10, 07745 Jena, Germany, kaus@econ.mpg.de.

1 Motivation

It is undisputable that the domestic use of solar thermal systems positively contributes to conserving natural resources and diminishing greenhouse gas emissions (Kalogirou, 2004; Tsoutsos et al., 2005). Moreover, to generate warm water and heating at home implies financial benefits for the household itself by reducing the energy bill during the product utilization phase such that the investment pays off over the product's life span. Recent consumer surveys indicate that consumers do acknowledge the environmental soundness and the potential financial benefits of solar thermal systems. However, the diffusion of this technology is still in its early stage in most European countries, including Germany.[1]

According to the findings of consumer surveys, the high initial capital costs, the long amortization time, low public subsidies as well as a lack of trust in the functionality and effectiveness of the technology impair the adoption of this product (Foster, 1993; Faiers and Neame, 2006; Watson et al., 2006). The difficulty to compare the performance across producers and installers is a further reason why the majority of consumers remain passive (Caird et al., 2008). In fact, many consumers make an acquisition dependent on solar thermal systems being more widespread, particularly on public buildings, and on the introduction of product labeling schemes (Faiers et al., 2007).[2]

While the financial barriers to product diffusion and the consumer assessment of product characteristics are by now well understood, i.e., aspects concerning the nature of solar thermal systems as a major investment, the motivational side of consumer behavior and its link to knowledge acquisition concerning a novel product has not received sufficient attention yet. Drawing upon the theory of learning consumers by Witt (2001) as well as Rogers' account of the diffusion of innovations (Rogers, 1995), further explanatory factors can be identified: environmental attitude, knowledge of the applicability of solar thermal systems to satisfy consumer needs, and the presence of this technology among peer consumers (peer group behavior).

We hypothesize that these factors play a different role at distinct stages of the stepwise diffusion process à la Rogers, which is why owners and nonowners are distinguished. We will refer to these consumer groups as pioneers and potential imitators respectively (for a similar approach, cf. Faiers et al., 2007; Caird et al., 2008). In contrast to prior studies, which primarily focused on explaining past adoptions (cf. Welsch and Kühling, 2009), this paper considers the determinants underlying the adoption decision within the next two to five years. We make use of a consumer survey, conducted in 2007 in the region of Hanover (Clausen, 2008), and distinguish the potential imitators' concrete plan to purchase a solar thermal system within the subsequent two years from the general interest to invest into this technology within the next five years. That way, we assess in how far the diffusion of solar thermal systems is self-sustaining or calls for further policy interventions.

The remainder of the paper is organized as follows. Section 2 outlines the theoretical background and derives the hypotheses. Section 3 introduces the data and the method. Descriptive and quantitative results are presented in section 4. At first, we group respondents into owners and nonowners of solar thermal systems in order to analyze whether system owners correspond to our definition of pioneer consumers. In a next

[1] Current owners are thus frequently referred to as "early adopters" in the sense of Rogers (1995) (Faiers and Neame, 2006; Caird et al., 2008, for studies in the UK).

[2] In Germany, a product labeling scheme does exist ("Blauer Engel").

step, we run probit-regressions for the potential pioneers' interest and the specific plan to acquire this technology, thereby testing the explanatory power of the aforementioned variables. The fifth and last section concludes.

2 Theoretical background and hypotheses

2.1 Consumption as a learning process

The theory of learning consumers ("learning-to-consume approach") by Witt (2001) is an essential element of the naturalistic approach to evolutionary economics as outlined in Witt (1987, 2003). This strand of literature explores the conditions of the emergence and diffusion of "novelty" - such as new scientific knowledge, product innovations, etc. - within society. And it postulates an intimate relationship between human biological and cultural evolution in the sense that cultural development is based upon as well as constrained by innate behavioral dispositions and cognitive learning abilities, which have emerged during human phylogeny. Hence, the naturalistic approach focuses on the explanation of long-run economic change from a biological and psychological perspective (Witt, 2008).[3]

The learning theory, more specifically, deals with the role of consumer motivations and learning processes in changing consumption patterns (Witt, 2001). It is at stark contrast with neoclassical consumer theory, which leaves open the question of why consumers regard certain products as useful and how they have come to form an understanding of product utility. Witt puts forth a more realistic account of consumption behavior which comprises notions of innate needs as well as cognitive and noncognitive learning processes (cf. Weiner, 1994; Anderson, 2000; Frieman, 2002). In the behavioral sciences, innate (or basic) needs are defined as primary reinforcers, encompassing among others food, sleep, health, and social recognition. Deprivation in terms of these basic needs motivates the organism, here: the consumer, to take action by which deprivation is removed. Whenever a novel act of consumption satisfies such needs, a sensory feedback is induced, whereby an association between product and need satisfaction is learnt. Acts of consumption categorized as pleasant will occur relatively more frequently with time, while consumption acts experienced as unpleasant will be avoided (Herrnstein, 1997). Besides this sensory-based elementary learning process, consumers purposefully look for new consumption opportunities and extend their behavioral repertoire through knowledge-based or cognitive learning. In this context, the use of media and the orientation toward peers (including other consumers) allows to reduce individual learning costs by benefiting from the experiences of others (cf. Bandura, 1986). Social learning produces a homogenization of consumption patterns within intensively interacting consumer groups. It attracts the consumers' attention to particular consumption solutions on the one hand, while accelerating changing consumption patterns on the other.

Certainly, these effects do not only result from the informative nature of the choices by other consumers (vicarious learning processes, cf. Cordes, 2004; Boyd and Richerson, 2005), but might also stem from the need for social recognition, i.e., the consumer's desire to appeal to their social environment (cf. Veblen, 1899; Leibenstein, 1950). In

[3] This approach is fundamentally different from the Neo-Schumpeterian branch, which makes direct use of analogies to the evolutionary theory of Darwin (variation and selection mechanism) (cf., e.g., Nelson and Winter, 1982; Hodgson, 2002).

empirical analysis, it is difficult to disentangle the two effects of information diffusion versus normative expectations. We therefore speak more in general of an impact of peer group behavior.

Finally, the consumption theory differentiates between types of goods on the basis of their nature to either directly or indirectly satisfy the underlying needs. Direct, sensory need satisfaction is derived from literally consumable goods such as food. In contrast to that, most durable goods, such as washing machines or solar thermal systems, are only indirectly capable of yielding need satisfaction through their product services. Take solar thermal systems, for example. The product itself does not evoke pleasant or unpleasant experiences when being put on the consumer's roof. Only through the product's services, released by its utilization, the need of upkeep of body temperature, for example, is satisfied.[4] Regarding the latter group of products, a cognitive learning process is needed, i.e., the acquisition of explicit consumer knowledge on the good's applicability to satisfy consumer needs, in order to develop an appreciation for the product.

2.2 Consumption as a diffusion process

The theory of innovation diffusion by Rogers (1995) aims to explain why consumers acquire a certain good at different points in time after its initial market introduction. According to Rogers, the course of product diffusion depends upon the distribution of specific consumer characteristics within the population of potential adopters. These characteristics encompass, among others, financial resources, social status, technological knowledge, and the general attitude towards novelty. Based on their characteristics, individuals can be categorized in terms of their position within the stepwise diffusion process.

According to Rogers' framework, diffusion starts with product adoption on the part of the so called "innovators." Advanced technological skills and sufficient financial resources allow these types of consumers to unreservedly appreciate new ideas and goods. Subsequently, the new good is purchased by the class of "early adopters." Being opinion leaders and role models, these consumers contribute to the dissemination of information on the new product and thus have the potential to mobilize further groups of buyers. The "early majority" reacts successively and with further delay. It is mainly the bandwagon effect (i.e., the motive of social desirability) which urges the "late majority" consumers to adopt the new good. Eventually "laggards", who are generally skeptical towards changes in consumption technology, reluctantly purchase the innovation. For them, the broad diffusion of the innovation has contributed to enhance their trust in the quality and usefulness of the novel good. Assuming certain relative shares of the different types of consumers within the population, which implies the probabilities for purchase to be normally distributed around the average time of adoption, the diffusion curve (i.e., the cumulative frequency distribution) takes an s-shaped course (Rogers, 1995, p.257 ff.). This means that the probabilities for purchase depend on the consumer's relative position within the sketched diffusion process along the time dimension (cf. Figure 1).[5]

[4]Naturally, it is also possible, but not per se the case, that such products show a direct link to consumer needs when they concern the social standing of a person, as in the case of status signals or conformity goods (cf. Veblen, 1899; Leibenstein, 1950).

[5]Naturally, the widespread diffusion of an innovation is by no means self-evident (Cooper, 1979).

Rogers (1995) emphasizes the heterogeneity of consumer types with respect to certain characteristics. Some of these characteristics, like general attitude towards novelty, are personal traits and thus relatively stable. Other attributes, however, might change with the course of time, for instance, financial resources. In addition to that, the nature of the product slightly transforms over time when it becomes more strongly linked to the motive of social desirability.[6] In sum, Rogers' account suggests that first adopters are both financially better-off (higher willingness to pay), but are also relatively more interested in the particular innovation than other consumers, thus taking action independent from the behavior of others. These consumers can be said to act on the basis of an intrinsic motivation as opposed to a concern for social approval. In the case of environmental innovations, environmentally conscious consumers would hence open up the diffusion as the "early adopters" (Coad et al., 2009).

Based on the theories by Witt and Rogers, the following preconditions of product adoption can be identified: firstly, a motivation for product acquisition, stemming from consumer needs, and either an intrinsic motivation (early adopters) or a concern for social approval (late adopters), and secondly, knowledge about the existence of a new good and its applicability for need satisfaction.

2.3 Hypotheses

The theory of learning consumers assigns consumption goods to different categories according to the good's capability to either directly or indirectly satisfy consumer needs. Only in the case of direct need satisfaction, product appreciation, and hence product adoption, can come about via noncognitive, sensory-based learning. The services provided by solar thermal systems (i.e., supply of warm water, heating, and air conditioning), in contrast, only indirectly satisfy the motives of health or hygiene and maintenance of body temperature. With regard to these motives, the adoption of solar thermal systems is thus contingent on cognitive learning by which consumers get to know the applicability of the product to satisfy those consumer needs. Product appreciation through cognitive learning is the more likely the more information about the good's features the consumer possesses, and it has to take place prior to the consumer's first purchase.[7]

Hypothesis 1: The higher the consumer's level of knowledge about the applications of solar thermal systems (*technological knowledge*), the higher her probability to purchase this product (H.1).

In the Rogers model consumers are categorized with respect to two criteria: their relative position within the diffusion process (i.e., timing of adoption) and the role that the behavior of other consumers plays for the individual decision. Essentially, all consumers can be assigned to two main groups, namely the "pioneers" versus the (po-

Likewise, the distribution of consumer characteristics within the population as assumed by Rogers, need not hold. We draw upon Rogers' account, nevertheless, because it highlights that product adoption takes place in a sequential manner and for different reasons, depending on the consumer type.

[6] We leave aside technical changes in the product make-up over the course of its diffusion.

[7] Beyond doubt, the consideration of the knowledge variable can also be justified on the grounds that the acquisition of a solar thermal system implies a major financial investment, which consumers carry out only after a careful analysis (Welsch and Kühling, 2009).

tential) "imitators." While the former have a positive attitude towards novelty and are intrinsically motivated to purchase the innovation (here: ecologically concerned consumers), adoption on the part of the latter is rather influenced by social desirability and/or (vicarious) social learning processes which reduce the uncertainty concerning the product's functioning and usefulness. However, when also imitators do possess a positive environmental attitude, it can be expected to increase the probability to adopt the new good, independent from the behavior of peers:

Hypothesis 2: The more positive the consumer's *environmental attitude*, the higher the probability that potential imitators decide to install a solar thermal system (H.2).

At the beginning of the diffusion process, the decision to adopt the innovation takes place independently from motives of social desirability as the bulk of consumers have not acquired the product yet such that social normative expectations could not have developed yet. In contrast to pioneers, potential imitators are expected to be influenced by the behavior of their peer group:

Hypothesis 3: The propagation of solar thermal systems in the consumer's social environment (i.e., *peer group behavior*) increases the probability of first-time purchases (H.3).

Please note that this hypothesis captures both potential effects of peer group behavior on individual choices: social desirability and (vicarious) social learning.

3 Method and data

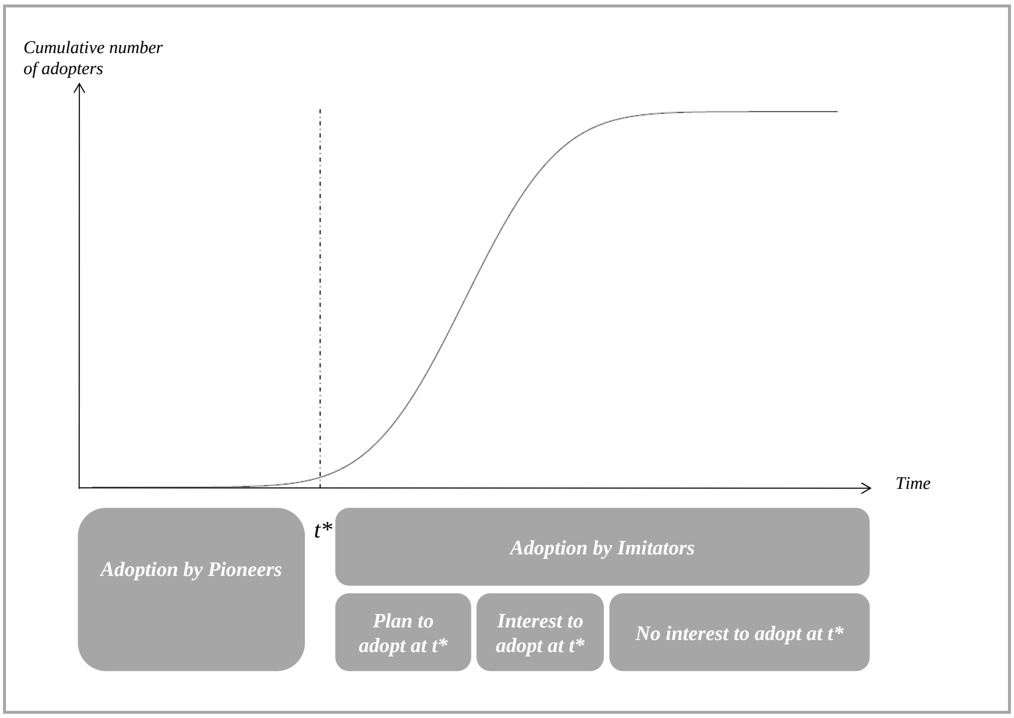
Differentiating between consumers on the basis of their ownership of solar thermal systems, we now examine the determinants of technology adoption exemplarily for the region of Hanover (North-West Germany). According to the aforementioned hypotheses, we expect certain factors to discriminate between consumers in terms of their prospective consumption behavior (more precisely, their stated intentions), namely environmental attitude, product knowledge and peer group behavior. The analysis aims at identifying if those factors do indeed increase the probability that adoption takes place (binary coded dependent variable). To that end, we estimate probit-models (cf. Welsch and Kühling, 2009, for a related approach).

The analysis builds on a survey of nearly 500 consumers, undertaken between July and September 2007 in the region of Hanover (for a detailed description of the survey as well as the institutional environment cf. Clausen, 2008).[8] In order to be able to specifically study the characteristics of the owners of solar thermal systems, this group of consumers is oversampled in the data.[9] The survey covers several socio-demographic characteristics, past and prospective consumption behavior (i.e., stated intentions),

[8]By focusing on one region only, institutional differences in energy supply are ruled out as explanatory factor of divergent adoption decisions.

[9]The sample consists of 139 solar thermal system owners (questionnaire via mail), 80 direct neighbors of solar thermal systems owners who do not possess a system themselves (face-to-face interviews), 122 green energy customers (questionnaire via mail), and 153 passerbys (face-to-face interviews). Unlike in Welsch and Kühling (2009) the estimations are not corrected for oversampling of owners as we analyze owners and potential imitators separately.

Figure 1: Idealized diffusion of a successful innovation



Notes: The figure sketches an idealized and successful diffusion process adapted from Rogers (1995, p.257 ff.). The Rogers model is modified in that only two consumer groups are distinguished. Prospective adoption is furthermore differentiated with respect to the stated intentions at time t*.

environmental attitude, consumption of peers, and knowledge regarding the functioning of solar thermal systems.

More in detail, respondents have been asked whether a solar thermal system is already installed at their home (yes, no). If the current owners correspond to our definition of pioneer consumers, they should differ from the nonowners with regard to certain criteria such as environmental attitude (cf. section 2). In addition, all consumers had to indicate whether they plan an installation of this technology for the next two years, or if this is at least of interest to them for the next five years (i.e., until 2012).[10] Based on these questions, the dependent variables $PLAN$ (yes, no) and $INTEREST$ (yes, no) have been generated. We analyze each of the dependent variables for the sample of potential imitators (first-purchase decision). Please note that we assume the mere interest to precede the specific plan in that the latter is closer to the actual adoption decision (cf. Figure 1) - which in turn is what the hypotheses relate to (cf. section 2.3). We therefore expect the aforementioned variables *in sum* to be relevant for the adoption decision. In other words, factors which discriminate between consumers at the level of interest need not distinguish between consumers in terms of their concrete plan to invest into this technology.

The hypotheses H.1 to H.3 regarding the impact of environmental attitude, consumer knowledge, and peer group behavior are tested on the basis of the following

[10] The exact wording of the questions and the specification of the variables are depicted in the appendix (Tables A1 and A2).

(independent) variables. The variable *KNOWLEDGE* gives the number of technological variants of solar thermal systems the consumer indicates to be familiar with (ranging from 1 to 4), which are warm water generation, the combination of warm water generation and heating, air conditioning (i.e., use of excess warmth for indoor cooling), and other.[11] While the first two options represent the most commonly used applications of solar thermal systems in Germany and other European countries, the third variant represents a rather new and less widespread application, which can be used supplementary to the first two options (cf. Clausen, 2008; Bundesministerium für Umwelt, 2010; Weiss and Mauthner, 2010).[12] Owners of solar thermal systems are expected to possess a better comprehension of the possibilities to employ solar thermal systems as compared to prospective adopters.[13]

The second hypothesis deals with the influence of the environmental attitude on consumer behavior. The survey offers a number of questions that could be used to capture this effect. Respondents reported to which degree they felt harassment by climate change, nuclear power plants and radioactive waste, and air pollution (each on a 1 to 5 rating scale).[14] Moreover, respondents have been asked to indicate their interest (*ENV_INTEREST*) in environmental issues as such (1 to 5 rating scale). In univariate regressions, only the variable relating to air pollution (*HARASS_3*) does not show any significant raw effect.[15] However, the raw effects of the remaining variables addressing feelings of harassment strongly resemble the effects of the environmental interest variable. As the latter is the most straightforward and intuitive variable to capture environmental attitude, *ENV_INTEREST* is maintained while the variables measuring feelings of harassment are omitted from the analysis.

The influence of the peer group's consumption on the adoption decision is tested via a binary variable (*BEHAVIOR_PEERS*), which indicates whether relatives, friends, or neighbors have already installed a solar thermal system. The analysis also controls for a couple of socio-demographic factors, namely household income, housing situation, age and sex of the respondent, marital status.

The control variables are justified as follows. As consumer surveys have shown the high financial burden of solar thermal systems to play a great role for the adoption decision (cf. section 1), it is necessary to control for household income as well as

[11] The survey does not contain questions which directly measure consumer knowledge of the need satisfaction potential of solar thermal systems. Questions inquiring into the familiarity with the different technical variants are the closest proxy to that issue. They do not imply a deep understanding of the technical details, but rather capture the associations that consumers hold with regard to this product.

[12] Please note that for the first three technical variants, closed questions have been posed in contrast to an open question regarding the fourth category.

[13] When interpreting technological knowledge in a very broad sense, one could argue that it is endogenous to the adoption intention (interest or plan) in that the intention simultaneously influences the accumulation of technological knowledge. We assume, however, that the gathering of information is preceded by only a general curiosity toward the issue and not a concrete purchase intention. Our approach thus applies to the relationship between the intention to adopt and the accumulation of very specific technological knowledge, which is necessary to understand the functioning of the product and its applicability to satisfy consumer needs. After that such specific knowledge is collected, intentions to adopt might be developed and trigger the collection of further information on the technology.

[14] These questions are based on the regular environmental awareness surveys of the German Federal Environment Agency (Umweltbundesamt, 2006).

[15] Univariate probit-regressions for all hypothesis-specific variables have been run prior to the hypotheses tests. Except for *HARASS_3*, all of the variables have been found to be significant. The full results are available upon request.

for real estate property.[16] As the installation of this technology means a substantial investment to a household, marital status and age of the respondent are also expected to matter. Particularly single person households can be expected to postpone such an investment until a stable family situation is reached. Hence, the probability of purchasing a solar thermal system is assumed to increase with age. At the same time, solar thermal systems are durables, the investment into which does pay off only after a certain time period, hence making the acquisition less attractive beyond a certain age. In sum, consumer age is specified both as level and square. It is furthermore known that men and women respond differently to technological novelties (Venkatesh et al., 2000), which is why sex is included as a further control variable.

The probit regressions are based on the following equations:

$$Pr(INTEREST_i = 1) = f(\alpha + \beta * K_i + \gamma * E_i + \delta * B_i + \epsilon * \mathbf{Dem_i} + \varepsilon_\mathbf{i})$$

$$Pr(PLAN_i = 1) = f(\alpha + \beta * K_i + \gamma * E_i + \delta * B_i + \epsilon * \mathbf{Dem_i} + \varepsilon_\mathbf{i})$$

where $Pr(INTEREST_i = 1)$ is the probability of being interested in purchasing a solar thermal system within the next five years, $Pr(PLAN_i = 1)$ is the probability of planning to purchase a solar thermal system within the next two years, K_i represents *KNOWLEDGE*, E_i *ENV_INTEREST*, and B_i *BEHAVIOR_PEERS*, and $\mathbf{Dem_i}$ is a vector of demographic variables, i.e., income, property, age, age squared, sex, and marital status.[17]

4 Empirical results

In this section, we examine the driving forces underlying the behavior of the potential imitators in the diffusion of solar thermal systems. In the first two subsections, descriptive statistics are used to qualitatively explore the data and to elaborate on the differences between consumer groups. Quantitative analysis follows to test the formerly outlined hypotheses.

4.1 Classifying consumers into groups of pioneers and potential imitators

As a consequence of the sampling procedure, a large share of the respondents are owners of a solar thermal system (i.e., 168 out of 494 respondents, cf. Table 1). From the mere number of owners we cannot infer which stage of the diffusion process of solar thermal systems has been reached yet in the region of Hanover. However, based on the theoretical frameworks by Rogers and Witt (Rogers, 1995; Witt, 2001), certain criteria for classifying the consumer groups of pioneers and imitators respectively have been

[16] Beyond doubt, owners of real estate have more degrees of freedom in their decision to install a solar thermal system as compared to renters.

[17] Compared to the study by Welsch and Kühling (2009), which makes use of the same data, this analysis does not exploit all available control variables. With respect to the smaller zero to one ratio of the dependent variables and the smaller sub samples analyzed here, the number of independent variables should rather be kept to a minimum (cf. e.g., Peduzzi et al., 1996; Long, 1997).

Table 1: Motives for past adoption of solar thermal systems (STS)

	Obs.	% of sample	% of owners	Financial reasons	Ecological reasons	Social reasons	Miscell. reasons
				(multiple indications possible)			
All owners	168	34.0	-	99 (58.9)	147 (87.5)	10 (6.0)	20 (11.9)
STS < 1 year	15	3.0	8.9	11 (73.3)	14 (93.3)	2 (13.3)	3 (20.0)
1 < STS < 2 years	26	5.3	15.5	17 (65.4)	23 (88.5)	4 (15.4)	4 (15.4)
2 < STS < 5 years	46	9.3	27.4	32 (69.6)	40 (87.0)	1 (2.2)	4 (8.7)
5 < STS < 10 years	59	12.0	35.1	31 (52.5)	52 (88.1)	1 (1.7)	7 (11.9)
STS > 10 years	12	2.4	7.1	3 (25.0)	11 (91.7)	2 (16.7)	1 (16.7)

Notes: The figures represent the number of observations. In brackets the relative shares are given, i.e., the number of observations (or indications) in this line divided by the total number of observations in this line.

identified: pioneers are expected to differ from imitators with respect to financial resources, technological knowledge of solar thermal systems, and the purchase motivation (i.e., an intrinsic motivation as opposed to a concern for social approval). Arguably, the diffusion of this technology is still in its early stage when current owners can be shown to match the pioneer definition.

Descriptive statistics provide some evidence to conclude that this is indeed the case. To begin with, owners of solar thermal systems predominantly indicate ecological reasons as a determinant of their decision to adopt (87.5%, cf. Table 1). Interestingly, this pattern is stable across the different age cohorts, i.e., the finding holds for owners who recently acquired the technology as much as for owners whose purchase took place more than 10 years ago.[18] It is further remarkable that the very early adopters to a much lesser extent name financial reasons as a motive behind the adoption decision than do the later adopters (25% as compared to ca. 73%). Hence, financial reasons (in the form of a reduced energy bill) have gained in importance over time.[19] This finding might indicate that the earliest adopters have not so much perceived the purchase as a form of investment which needs to pay off financially. Furthermore, the share of consumers who indicates the role of the social environment, i.e., peer group behavior, to be important is very low (6% of all owners). Finally, the mean household income of owners exceeds the average income of potential imitators by almost 40% (cf. Table 2). These findings corroborate our conjecture that the market for solar thermal systems is still in that stage of diffusion where mainly pioneer consumers (in the sense of Rogers, 1995) have acquired this technology, i.e., for whom ecological concerns rather than financial benefits and social desirability were decisive purchase motives.[20]

Table 2 further substantiates that current owners represent rather intrinsically motivated consumers who are financially well-off and possess sound technological knowledge. Comparing the group means for owners and nonowners in terms of novelty attitude (3.93 versus 3.79), environmental attitude (4.35 versus 4.17), and technological knowledge (2.17 versus 1.93) we find that the mean values for owners clearly exceed the values for nonowners.[21] T-tests show that except for novelty attitude, all group means are significantly different at the 5% level.

[18] About 6% of solar thermal system owners did not indicate the system's age.

[19] Rising energy prices and changes in environmental policy (e.g., subsidies) might also have contributed to this development.

[20] This finding is also in accordance with prior research (cf. Sultan and Winer, 1993; Clausen, 2008).

[21] As a caveat, the survey does not provide information about the attitude toward novelty and technological knowledge at the time of the adoption decision.

Table 2: Means of hypothesis-specific variables across consumer groups

Variable	Pioneers	Potential imitators			
		All	Plan	Interest	No intention
Environmental interest	4.35	4.17	4.62	4.46	4.01
Novelty attitude	3.93	3.79	4.00	3.91	3.72
Knowledge	2.17	1.93	2.31	2.14	1.84
Behavior peers	0.68	0.53	0.92	0.57	0.49
Income	4075	2955	3568	3224	2871
Obs.	168	326	13	85	220

Notes: Except for the number of observations all values are variable means. The number of observations do not add up as for 13 observations either *PLAN* or *INTEREST* was not indicated. In the case of *BEHAVIOR_PEERS* the numbers can be interpreted as percentage shares.

4.2 Qualitative findings on prospective consumer behavior

The survey allows to cautiously draw some inferences about the development of the demand for solar thermal systems within the subsequent five years (cf. Table 2, lowermost row). The share of respondents who state to be interested in purchasing this technology amounts to about 30% of current nonowners (85 out of 326). A much smaller number of consumers indicates to have made concrete plans in that respect, namely about 5% of the respondents (13 out of 326). These statistics clearly do not indicate a strong, self-sustaining take-off of the diffusion of solar thermal systems. However, if it was possible to convert the mere interest into concrete actions, the market for solar thermal systems in North-West Germany would witness a substantial growth, moving the diffusion process further. In subsection 4.3, therefore, we scrutinize in more detail, which factors play a decisive role in the adoption process.

For now, let us take a closer look at the subgroup of potential imitators, which are divided into "planners", interested consumers and consumers with no intention to act. According to the first hypothesis, higher technological knowledge on the product is expected to increase the probability of further investments into this technology. The expected positive correlation between level of knowledge and adoption probability appears to hold: the nonowners without intention display the lowest mean values, while those nonowners planning to adopt show the highest mean values of the knowledge variable.

With regard to the second hypothesis, descriptive statistics largely confirm the conjecture. The planners show the highest mean values for environmental attitude, and those who have no intention to adopt the lowest ones.

The third hypothesis deals with the impact of peer group consumption on consumer behavior. Table 2 reveals that the percentage of peers owning a solar thermal system is higher among owners as compared to the potential imitators (68% vs. 53%). In the case of the owners, however, this result is not to be interpreted in the way that these consumers are affected by the consumption of others: system owners have clearly indicated the opposite (cf. Table 1, column six).[22] More meaningful are the figures for

[22]The presented figures refer to current peer consumption, and it is not unlikely that pioneer consumers have had an effect on their close social surroundings in terms of stimulating imitation on the part of the latter. Another plausible explanation is that pioneers themselves are socially connected in that they have acquired the environmentally benign technology in a joint endeavor.

the group of potential imitators. Here, the relative share of peers possessing a solar thermal system is larger among planners as compared to interested consumers (92% versus 57%). The finding might indicate that peer group behavior indeed unfolds an effect on the consumption choices of the individual, either as a source of information or in the form of social normative expectations (social desirability).[23]

4.3 Quantitative results

The descriptive findings gathered thus far convey a first impression of the determinants of past and future adoptions of solar thermal systems. They also illustrate how consumer groups differ with respect to such factors, thus demonstrating the usefulness of applying the theory outlined in section 2. In what follows, we examine the determinants of the prospective diffusion of solar thermal systems from a quantitative perspective.

4.3.1 Determinants of the interest to adopt a solar thermal system

The imitator's decision to purchase a solar thermal system is hypothesized to depend on the consumer's knowledge, her environmental attitude, and the behavior of peers. Arguably, socio-demographic factors and technology-specific characteristics also play a role. Table 3 depicts the results of probit models concerning the *INTEREST* to purchase a solar thermal system within the next five years. Three model specifications are used to analyze each of the hypotheses sequentially. The first specification shows the raw effect of the hypothesis-specific variable. Thereupon, control variables are included. Due to multicollinearity, which is caused by the high correlation in age and its square term, the effect of income cannot be calculated precisely. Therefore, the second specification introduces only income related control variables to accurately estimate the effect of income, while the third specification uses the full set of control variables.[24] The sequential introduction of control variables moreover allows evaluating the robustness of each of the hypothesis-specific variables. The tenth specification gives the results of the full model.[25]

Overall, the estimations yield some robust results (cf. Table 3). To begin with, the impact of age that was conjectured to follow an inverted-U shape, strongly complies with the expectations. While the coefficient is positive and significant for the age variable as such, it is negative and significant for the squared age variable.[26] A further pattern is found for the variables which measure the financial wealth of the household: when adding the variables property and income to each of the basic specifications, a significant positive effect of income on the interest to adopt is found. Ownership of

[23]The exact form of this impact cannot be detected by this analysis.

[24]After including the remaining control variables, household income is no longer significant. This result stems from a multicollinearity problem, as indicated by the high correlation in age and its square term (0.98, cf. Table A3) and the high variance inflation factors of age and its square term (>40). Results other than income are not affected. Therefore, the age variables are omitted in the final specification (10).

[25]The last specification uses only control variables with a *p-value* smaller than 0.5 to omit variables that do not contribute to the model fit. Marital status is therefore dropped from the full model.

[26]Examining the relationship in more depth reveals that the turn to a negative relationship occurs at the high end of the age distribution. The relationship within our sample is hence rather increasing at a decreasing rate.

Table 3: Determinants of the interest to purchase a solar thermal system

Variables	Specifications									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hypothesis-specific variables										
Knowledge	0.070***	0.062**	0.061**							0.039
	(0.027)	(0.030)	(0.031)							(0.032)
Environmental interest				0.107***	0.103***	0.108***				0.094***
				(0.028)	(0.032)	(0.032)				(0.034)
Behavior peers							0.061	0.023	0.010	-0.002
							(0.051)	(0.059)	(0.059)	(0.058)
Household controls										
Income		0.00004**	0.00003		0.00003*	0.00002		0.00004**	0.00002	0.00003*
		(0.00002)	(0.00002)		(0.00002)	(0.00002)		(0.00002)	(0.00002)	(0.00002)
Property		-0.083	-0.059		-0.076	-0.046		-0.089	-0.069	-0.075
		(0.063)	(0.070)		(0.062)	(0.069)		(0.064)	(0.072)	(0.063)
Age			0.021*			0.023*			0.024*	
			(0.013)			(0.013)			(0.013)	
Age^2			-0.0003*			-0.0003**			-0.0003**	
			(0.0001)			(0.0001)			(0.0001)	
Sex			0.041			0.036			0.034	0.047
			(0.057)			(0.056)			(0.057)	(0.056)
Marital status			0.038			0.040			0.050	
			(0.068)			(0.068)			(0.069)	
Prob>Chi^2	0.0099	0.0448	0.0549	0.0001	0.0027	0.0033	0.2348	0.2235	0.1665	0.0164
$Pseudo-R^2$	0.0183	0.0255	0.0438	0.0398	0.0448	0.0679	0.0039	0.0140	0.0335	0.0499
Obs.	310	262	261	309	262	261	306	259	258	259

Notes: The coefficients denote *mean* marginal effects. In case of binary independent variables discrete changes instead of marginal changes are indicated. *** (**, *) Significant at the 1% (5%, 10%) level.

real estate, sex, and marital status do not appear to influence the respondent's interest to adopt a solar thermal system.

In terms of the hypothesis-specific variables, knowledge and environmental attitude have a significant positive effect throughout. The coefficients are also robust to the inclusion of control variables. These results thus comply with the expectations formulated in hypotheses H.1 and H.2. The peer variable, however, does not show a significant effect once the control variables are included. Consequently, the data at hand does not support hypothesis H.3 that the social environment effects the consumers' interest to adopt a solar thermal system.

Running the full model yields another interesting insight, namely that the environmental attitude offsets the significance of the knowledge variable. Hence, although differences in knowledge seem to be an important determinant of being interested in the adoption of solar thermal systems, the accumulation of technological knowledge can be seen as a by-product of the imitators' interest in environmental issues.[27] Environmental attitude appears to be the most important determinant of being interested in purchasing a solar thermal system within the next five years.

4.3.2 Determinants of the plan to adopt a solar thermal system

Next, we analyze the potential imitator's $PLAN$ to adopt and find the results to vary strongly from the $INTEREST$ to adopt (cf. Table 4). Although income does not explain the consumer's plan to adopt, the property variable does, which is another income-related variable. Running the model without the peer variable, which is positively correlated with the property variable (0.25, cf. Table A3), the property variable turns out to positively influence the plan to adopt. When introducing the peer variable, however, it absorbs some explanatory power of the property variable.

The most striking result is the shift in the impact of the hypothesis-specific variables. While the conjectured effects concerning technological knowledge and environ-

[27]This finding supports the consumer specialization hypothesis by Witt (2001), according to which consumer interest into a subject and consumer knowledge on the issue are closely interlinked.

Table 4: Determinants of the plan to purchase a solar thermal system

Variables	Specifications									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Hypothesis-specific variables										
Knowledge	0.020	0.016	0.014							0.003
	(0.014)	(0.015)	(0.015)							(0.016)
Environmental interest				0.027*	0.017	0.015				0.012
				(0.016)	(0.016)	(0.016)				(0.016)
Behavior peers							0.065***	0.049**	0.060**	0.050**
							(0.021)	(0.023)	(0.025)	(0.023)
Household controls										
Income		0.000001	-0.0000008		0.0000005	-0.000002		-0.0000005	-0.000004	-0.000002
		(0.000008)	(0.00001)		(0.000008)	(0.000009)		(0.000008)	(0.00001)	(0.000008)
Property		0.055*	0.041		0.055**	0.041		0.039	0.017	0.035
		(0.028)	(0.027)		(0.028)	(0.027)		(0.026)	(0.029)	(0.026)
Age			0.007			0.006			0.008	
			(0.008)			(0.008)			(0.008)	
Age^2			-.00005			-0.00005			-0.00006	
			(0.00007)			(0.00007)			(0.00007)	
Sex			-0.015			-0.017			-0.029	-0.030
			(0.025)			(0.024)			(0.024)	(0.024)
Marital status			-0.005			-0.003			-0.008	
			(0.032)			(0.031)			(0.032)	
Prob>Chi^2	0.1152	0.0568	0.1833	0.0486	0.0577	0.1783	0.0014	0.0171	0.0370	0.0470
$Pseudo-R^2$	0.0228	0.0817	0.1096	0.0357	0.0813	0.1106	0.0944	0.1108	0.1625	0.1389
Obs.	323	273	272	322	273	272	318	269	268	269

Notes: The coefficients denote *mean* marginal effects. In case of binary independent variables discrete changes instead of marginal changes are indicated. *** (**, *) Significant at the 1% (5%, 10%) level.

mental attitude have been confirmed before, the peer variable now stands out as being the only significant variable in context with the concrete adoption plan. The results thus support hypothesis H.3 but not H.1 and H.2. Taking together the findings for $INTEREST$ and $PLAN$ to adopt, the hypotheses are supported in sum, however (cf. section 3), thus substantiating our conjecture that interest and plan follow up on one another. Take a look at the figures in Table 2 (subgroup means): in terms of knowledge and environmental attitude the "planning imitators" show the highest values throughout. Therefore, we argue that environmental attitude and technological knowledge are necessary as a prerequisite for the imitator's plan to adopt. The behavior of peers, however, appears to act as a trigger for the concrete decision to adopt.

4.4 Discussion of results

Overall, the results of the descriptive and the quantitative analyses comply favorably with the theoretical predictions. Respondents could be divided into pioneers and potential imitators in that current owners of solar thermal systems were found to be fundamentally different from nonowners in terms of income, knowledge, novelty attitude, and environmental attitude. The descriptive analysis demonstrates that it is possible and worthwhile to further subdivide consumer groups according to the degree of their stated intention, i.e., differentiating mere interest from the concrete plan to adopt. Apparently, the group of potential imitators is heterogeneous as well, and respondents who plan to adopt are one step ahead of those who are merely interested.

The results of the quantitative analysis are summarized in Table 5. While environmental attitude and consumer knowledge turned out to positively influence the nonowners' interest to adopt a solar thermal system, the behavior of peers was a significant factor only in context with the concrete plan to adopt. Moreover, income positively affects the consumer's interest but not the plan to purchase, while the relationship is reversed for property. It is also worthwhile to note that the dominating factor in generating interest in the technology is the consumer's environmental attitude, which accounts for the effect of knowledge.

Table 5: Summary of hypotheses and results

Variable	Potential imitators		
	Hypotheses	Results	
		Interest	Plan
Knowledge (H.1)	+	+	.
Environmental interest (H.2)	+	+	.
Behavior peers (H.3)	+	.	+

Notes: This table summarizes the hypothesis-specific effects from Table 3 and 4.
(+) denotes a significant positive effect.
(-) denotes a significant negative effect.
(.) denotes the absence of any significant effect.

In sum, knowledge, environmental attitude, and income seem to be important but not sufficient determinants of prospective purchases of solar thermal systems. Only the behavior of peers appears to act as a trigger to the diffusion of this technology: once an interest for the product has been generated, the activities of the social environment decide if the installation of a solar thermal system is eventually envisaged or not. This result is very much in line with findings of earlier studies, which emphasized consumers' skepticism toward the technology and the decisive role of the behavior of others (Faiers and Neame, 2006; Faiers et al., 2007). In that regard, increasing the visibility of purchases and enhancing consumers' communication about product information might be central factors speeding up the diffusion process. In addition, it is essential that environmental campaigns maintain the perception of solar thermal systems as an environmentally benign technology, thus appealing to environmentally concerned consumers who are looking for consumption opportunities.

There are a couple of limitations to this analysis. First, we cannot identify which effect exactly peer group behavior unfolds on the adoption decision; the questionnaire does not allow to separate the effect of information dissemination on the existence and usefulness of new products from social normative expectations. Second, only stated intentions and not actual consumer behavior is measured, which is why the figures on the future diffusion of solar thermal systems have to be interpreted with caution.

5 Conclusions

The aim of this paper was to shed light on the driving forces underlying the adoption of solar thermal systems. Although solar thermal systems have been available in Germany for nearly three decades, the diffusion process of this technology is still in its infancy. Making use of a consumer survey in the region of Hanover in 2007, we particularly analyzed the determinants of *prospective* first-time-purchases of this technology, i.e., the adoption decision by nonowners. Drawing on theoretical foundations from innovation economics and evolutionary consumer theory, some testable hypotheses on the impact of consumer motivations and knowledge have been derived.

The theory of innovation diffusion by Rogers (1995) posits that new products diffuse successively within a potential market as groups of consumers differ in terms of certain characteristics and motivations to adopt. Basically two groups of "pioneers" versus potential "imitators" can be distinguished on the basis of the extent to which their consumption behavior stems from an intrinsic motivation, here: environmental interest (pioneers), as opposed to a concern for social approval, i.e., meeting the normative expectations of others (imitators). The theory of learning consumers (Witt, 2001) emphasizes the different ways by which consumers learn to appreciate new goods. For solar thermal systems, cognitive learning processes play a central role, i.e., the acquisition of knowledge about the applicability of the product for satisfying consumer needs. In this context, the social environment might affect consumer behavior by acting as a source of information.

Given the findings from the consumer survey in North-West Germany analyzed here, the future path of product diffusion is, at best, moderate. Roughly one third of the survey respondents currently not owning a solar thermal system indicate to be interested in the acquisition of this technology, whereas only about 5% of the nonowners appear to have specific plans already (first-time purchase on the part of the potential imitators). Inquiring into their characteristics and motives, we find the "interested" consumers to possess a relatively strong interest in environmental issues and a good understanding of the ways by which solar thermal systems can appeal to consumer needs. Specifically the environmental attitude appears to be a decisive factor here. The behavior of peers, i.e., the propagation of solar thermal systems in the consumer's immediate social surroundings, in contrast, is the essential when it comes to the concrete adoption plan.

References

Anderson, J. R. (2000). *Cognitive Psychology and its Implications*. Worth Publishers, New York.

Bandura, A. (1986). *Social foundations of thought and action: a social cognitive theory*. Prentice-Hall, Englewood Cliffs/NJ.

Boyd, R. and Richerson, P. J. (2005). *The origin and evolution of cultures*. Oxford University Press, Oxford.

Bundesministerium für Umwelt, N. u. R. B. (2010). Erneuerbare energien in zahlen: Nationale und internationale entwicklung. (available at: http://www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/broschuere_ee_zahlen_bf.pdf).

Caird, S., Roy, R., and Herring, H. (2008). Improving the energy performance of uk households: Results from surveys of consumer adoption and use of low- and zero-carbon technologies. *Energy Efficiency*, 1 (2):149–166.

Clausen, J. (2008). Feldvermessungsstudie Klimaschutzregion Hannover: Überblick über das Praxisfeld und die Fokusbereiche Solarthermie und Ökostrom im Rahmen des Forschungsprojektes Wenke^2.$WENKE^2 - Diskussionspapier 3/2008$.

Coad, A., de Haan, P., and Woersdorfer, J. S. (2009). Consumer support for environmental policies: An application to purchases of green cars. *Ecological Economics*, 68(7):2078 – 2086.

Cooper, R. G. (1979). The dimensions of industrial new product success and failure. *The Journal of Marketing*, 43(3):pp. 93–103.

Cordes, C. (2004). The human adaptation for culture and its behavioral implications. *Journal of Bioeconomics*, 6 (2):143–163.

Faiers, A. and Neame, C. (2006). Consumer attitudes towards domestic solar power systems. *Energy Policy*, 34(14):1797–1806.

Faiers, A., Neame, C., and Cook, M. (2007). The adoption of domestic solar-power systems: Do consumers assess product attributes in a stepwise process? *Energy Policy*, 35(6):3418–3423.

Foster, J. (1993). Solar water heating in queensland: the roles of innovation attributes, attitudes and information in the adoption process. *Prometheus*, 11 (2):219–233.

Frieman, J. L. (2002). *Learning and Adaptive Behavior*. Wadsworth, Belmont.

Herrnstein, R. J. (1997). *The Matching Law*. Harvard University Press, Cambridge/MA.

Hodgson, G. M. (2002). Darwinism in economics: from analogy to ontology. *Journal of Evolutionary Economics*, 12(3):259–281.

Kalogirou, S. A. (2004). Environmental benefits of domestic solar energy systems. *Energy Conversion and Management*, 45(18-19):3075 – 3092.

Leibenstein, H. (1950). Bandwagon, snob, and veblen effects in the theory of consumers' demand. *The Quarterly Journal of Economics*, 64(2):183–207.

Long, J. S. (1997). *Regression models for categorical and limited dependent variables*. Sage Publications, Thousand Oaks, CA.

Nelson, R. R. and Winter, S. G. (1982). *An evolutionary theory of economic change*. Harvard University Press, Cambridge/MA.

Peduzzi, P., Concato, J., Kemper, E., Holford, T. R., and R., F. A. (1996). A simulation study of the number of events per variable in logistic regression analysis. *Journal of Clinical Epidemiology*, 49(12):1373–1379.

Rogers, E. M. (1995). *Diffusion of innovations*. The Free Press, New York.

Sultan, F. and Winer, R. S. (1993). Time preferences for products and attributes and the adoption of technologydriven consumer durable innovations. *Journal of Economic Psychology*, 14(4):587 – 613.

Tsoutsos, T., Frantzeskaki, N., and Gekas, V. (2005). Environmental impacts from the solar energy technologies. *Energy Policy*, 33(3):289–296.

Umweltbundesamt (2006). Fragebogen umweltbewusstsein 2006. (available at: http://www.umweltbewusstsein.de/deutsch/2006/download/ub2006_fragebogen.pdf).

Veblen, T. (1899). *The Theory of the Leisure Class: Economic Study of Institutions*. Random House, New York.

Venkatesh, V., Morris, M. G., and Ackerman, P. L. (2000). A longitudinal field investigation of gender differences in individual technology adoption decision-making processes. *Organizational Behavior and Human Decision Processes*, 83(1):33 – 60.

Watson, J., Sauter, R., Bahaj, B., James, P. A., Myers, L., and Wing, R. (2006). Unlocking the power house: Policy and system change for domestic micro-generation in the UK.

Weiner, B. (1994). *Motivationspsychologie*. Beltz Psychologie-Verlagsunion, Weinheim.

Weiss, W. and Mauthner, F. (2010). Solar heat worldwide: Markets and contribution to the energy supply 2008. Technical report, IEA Solar Heating & Cooling Programme. (available at: http://www.iea-shc.org/publications/downloads/Solar_Heat_Worldwide-2010.pdf).

Welsch, H. and Kühling, J. (2009). Determinants of pro-environmental consumption: The role of reference groups and routine behavior. *Ecological Economics*, 69(1):166–176.

Witt, U. (1987). *Individualistische Grundlagen der evolutorischen Ökonomik*. Mohr (Siebeck), Tübingen.

Witt, U. (2001). Learning to consume - a theory of wants and the growth of demand. *Journal of Evolutionary Economics*, 11(1):23–36.

Witt, U. (2003). *The Evolving Economy Essays on the Evolutionary Approach to Economics*. Edward Elgar, Aldershot.

Witt, U. (2008). What is specific about evolutionary economics? *Journal of Evolutionary Economics*, 18(5):547–575.

A Data appendix

Table A1: Specification of control variables

Variable	Specification
INCOME	mean monthly income (inc) restricted to categories (in €): 500 if inc<1000, 1250 if 1000<inc<1500, 1750 if 1500<inc<2000, 2250 if 2000<inc<2500, 2750 if 2500<inc<3000, 3250 if 3000<inc<3500, 3750 if 3500<inc<4000, 4250 if 4000<inc<4500, 4750 if 4500<inc<5000, 5500 if inc >5000
PROPERTY	1 if house or flat is owned, 0 if different
MARITAL STATUS	1 if maried or life partnership, 0 if divorced or living apart or widowed
AGE	mean age restricted to categories: 18 if age <20, 25 if 20<age<30, 35 if 30<age<40, 45 if 40<age<50, 55 if 50<age<60, 65 if 60<age<70, 75 if age >70
AGE^2	square of *AGE*
SEX	1 if female, 0 if male

Table A2: Survey questions

Variable	Question
Dependent Variables	
PLAN	Do you plan to install or extend a solar thermal system (STS) within the next two years? (1 if yes, 0 if no)
INTEREST	Would you be interested in installing or extending one of the mentioned modes of usage within the next five years?* (1 if yes, 0 if no)
Independent variables	
KNOWLEDGE	Do you know the following modes of usage of STSs (multiple answers possible): (1) warm water supply, (2) combined use of warm water supply and heating support via larger collector area, (3) use of excess warmth for supplementary indoor cooling, (4) other (indicate which)
HARASS_1	How dangerous would you say is a worldwide climate change caused by the green house effect for you and your family? (1) not dangerous at all, (2) not so dangerous, (3) slightly dangerous, (4) very dangerous, (5) extremely dangerous
HARASS_2	How dangerous would you say are nuclear plants and the resulting radioactive waste for you and your family? (1) not dangerous at all, (2) not so dangerous, (3) slightly dangerous, (4) very dangerous, (5) extremely dangerous
HARASS_3	How dangerous would you say is the air pollution caused by cars and the industry for you and your family? (1) not dangerous at all, (2) not so dangerous, (3) slightly dangerous, (4) very dangerous, (5) extremely dangerous
ENV_INTEREST	Are your interested in environmnetal issues? Rank in five steps between (1) not interested to (5) highly interested
NOVELTY	Are you open minded towards novelty? Rank in five steps between (1) not open minded to (5) very open minded
BEHAVIOR_PEERS	Do your relatives, friends, or neighbors own a STS? (1 if yes, 0 if no)

Notes: The survey was undertaken in German.
* The question refers to the options given in the knowledge related question (*KNOWLEDGE*).

Table A3: Contemporaneous correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Knowledge	1								
(2) Environmental interest	0.1879	1							
	(0.0000)								
(3) Behavior peers	0.0995	0.0909	1						
	(0.0281)	(0.0461)							
(4) Income	0.0677	0.0353	0.2431	1					
	(0.1616)	(0.4679)	(0.0000)						
(5) Property	0.0316	0.0675	0.2477	0.5427	1				
	(0.4841)	(0.1360)	(0.0000)	(0.0000)					
(6) Age	0.0181	0.1294	0.0236	0.2588	0.4770	1			
	(0.6882)	(0.0042)	(0.6038)	(0.0000)	(0.0000)				
(7) Age^2	-0.0159	0.1203	0.0131	0.1887	0.4265	0.9850	1		
	(0.7257)	(0.0079)	(0.7741)	(0.0001)	(0.0000)	(0.0000)			
(8) Sex	-0.1791	-0.014	-0.0508	-0.2283	-0.1677	-0.2041	-0.1685	1	
	(0.0001)	(0.7574)	(0.2645)	(0.0000)	(0.0002)	(0.0000)	(0.0002)		
(9) Marital status	0.0486	0.0336	0.2055	0.5596	0.5168	0.2857	0.2379	-0.2731	1
	(0.2832)	(0.4601)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	

Notes: The table reports pairwise correlations between the regressors.